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GB 2301811 A EP 0172301 A1 WO 95/29867 A1

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INT CL^6 **B66B 9/08 , G01B 5/30 7/16 7/24 , G01C 9/00 9/02 9/08 9/14 9/16**
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(54) Abstract Title
Annular ring inclinometer

(57) The inclination of a structure A eg the seat of a stair lift is measured using an inclinometer attached to the structure comprising an arm section B carrying a strain measuring sensor C. An inertial mass O is attached to the end of the arm section B and any deviation in inclination of the structure results in strain being detected by the measuring element C. The inertial mass comprises a ring of material which is free to rotate about the axis of the bearing about which the seat frame rotates relative to the chassis.

The output of the sensor is used to maintain the seat in a horizonal position at all times.

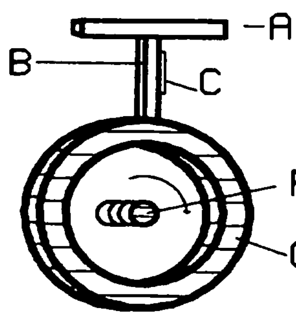

FIG7

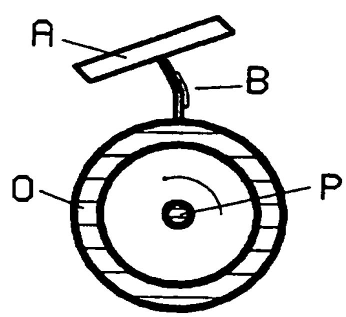

FIG8

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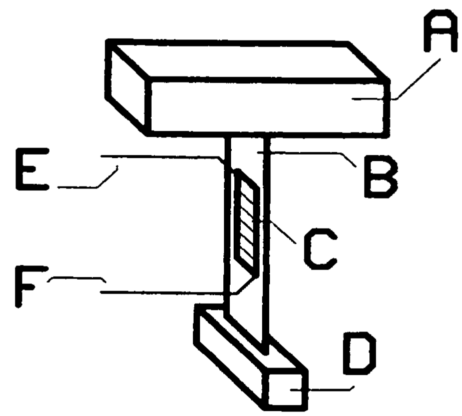

FIG1

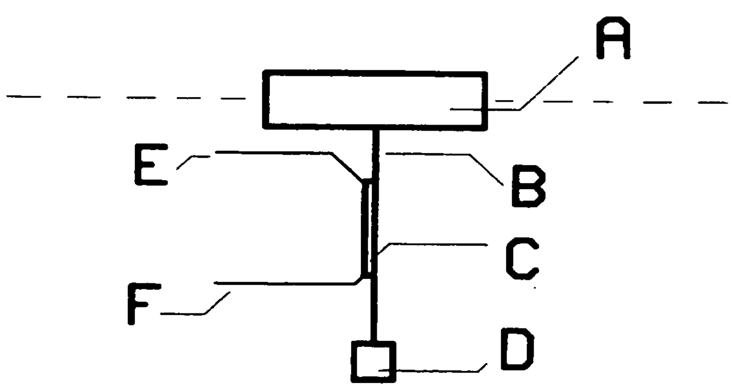

FIG2

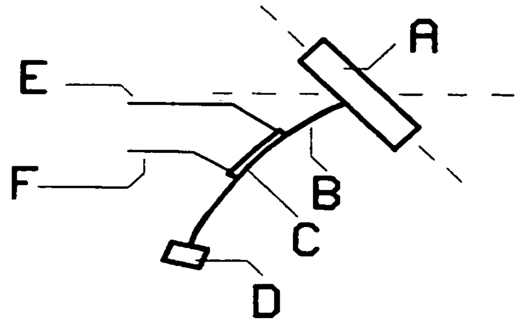

FIG3

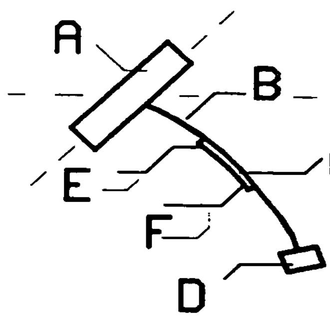

FIG 4

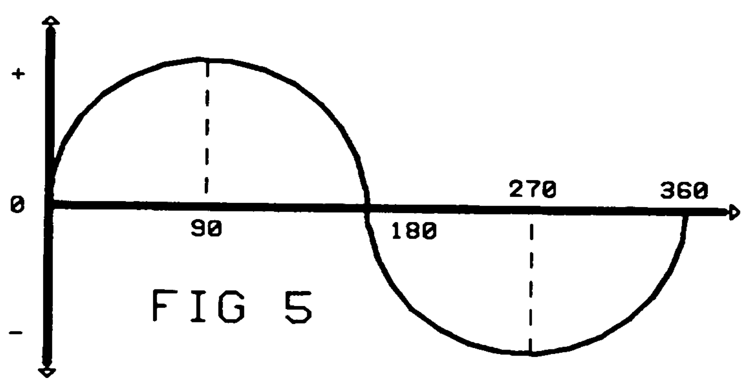

FIG 5

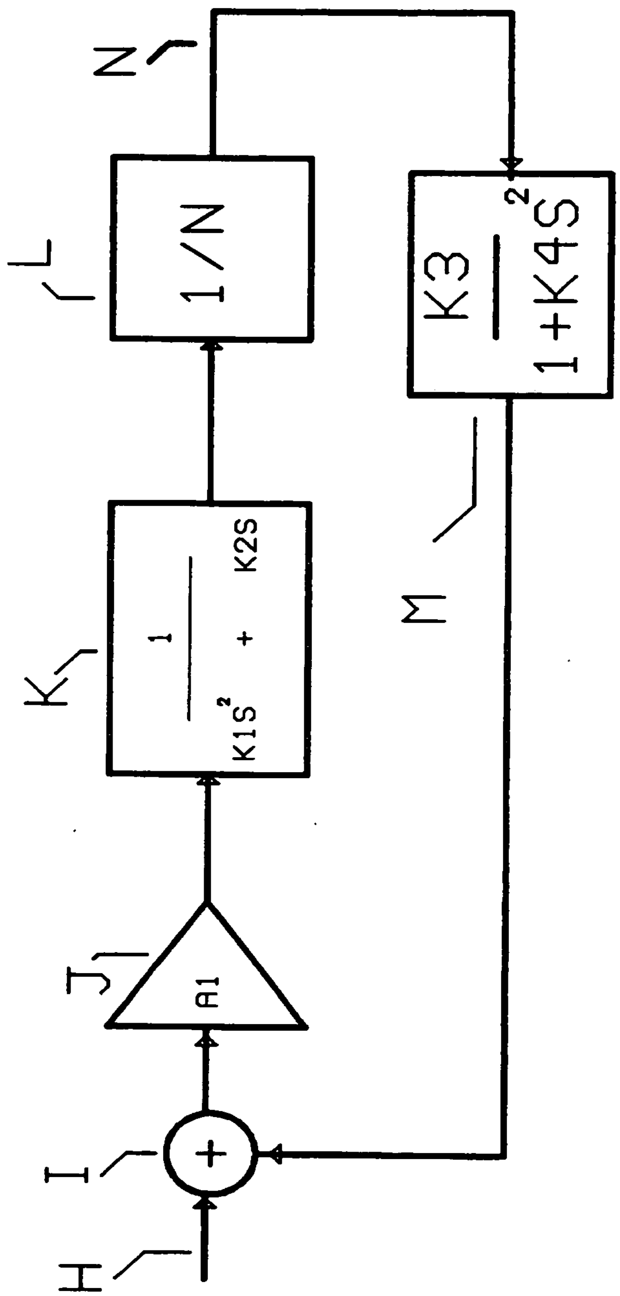

FIG 6

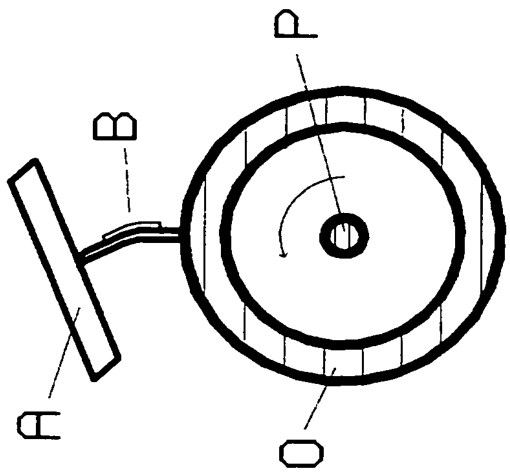

FIG8

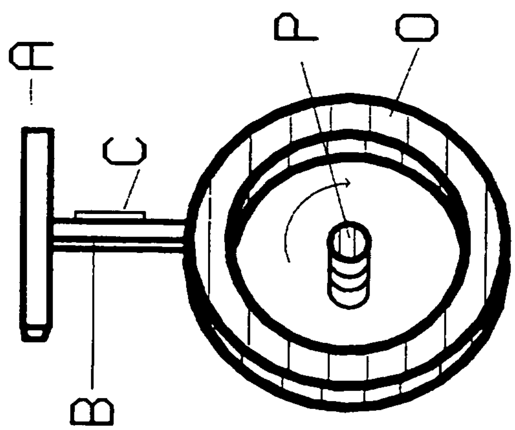

FIG7

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LEVELLING STAIRLIFTS WITH THE ANNULAR RING INCLINOMETER

The recent advancements in stairlift design has led to the introduction new types of rail. Rails have previously mechanically contributed to the process of seat-levelling by the use of skates, push-rods and lever arrangements necessary to keep the seat horizontal to the floor throughout its travel.

An alternative method of seat levelling could be achieved by using an electric motor coupled to a suitable gearbox or mechanism such as a worm drive which adjusts the angle of the seat. When the carriage changes from one gradient to another a correcting signal is fed to the motor. This correcting signal helps to maintain the seat in a level attitude.

One obvious choice for generating an error signal reflecting the change of angle would involve the use of a pendulum, and the idea of using a pendulum connected to a suitable feedback device such as a potentiometer is certainly not new. If the seat angle changes, The pendulum remains vertical due to gravity and the output from the position sensor to which the pendulum is connected is fed to the motor drive as an input. The motor then drives the seat in a direction opposing the change until the position sensor output returns to the value which represents a horizontal seat.

For the seat to remain parallel to the zero degree axis the levelling system must respond fast enough to counteract the tendency for the seat to follow the changes in gradient to be encountered at normal stairlift operating speeds. These angular changes occur in the range of 12 deg/sec to 30deg/sec.

Although a pendulum seems to be a simple and effective means of providing a seat levelling error signal, it has a fundamental drawback; the natural resonant frequency of the pendulum itself which is typically less than 3Hz. F=0.5/sqtL and in order to increase F the length of the pendulum (L) becomes impossibly short. Such a system would require the use of a pendulum with a natural resonant frequency much higher than 3Hz ideally greater than 30Hz so that the system responds to average changes of pendulum angle and rejects instantaneous values due to the pendulum swinging back and forth. It may be possible to design a pendulum to have a higher natural resonance but it would be prohibitively expensive and possibly unproducable.

For the seat to remain parallel to the zero degree axis within an acceptable limit, the control loop bandwidth must be tailored to allow a seat response of 30 deg/sec which requires a bandwidth of 3Hz. Thus the resonant frequency of an economic pendulum is in the passband of the control loop and uncontrollable motion of the seat would occur. (Instability)

It is therefore necessary to detect a change of gradient, and generate a correcting error signal with a device whose natural resonant frequency falls outside the 3Hz bandwidth, and can produce a useful signal to maintain seat stability within acceptable limits. These limits are typically plus or minus 2 deg from horizontal.

Such a device, or sensor, is the subject of this patent application, and its use is suitable for, but not restricted to seat levelling in a Stairlift. There are other applications such as stabilised platforms and stabilised camera imaging as well as accelleration and decelleration detection.

The arrangement of a suitable sensor is shown in fig 1.

The block -A- is fixed to the surface, the angle of which is to be monitored. Clamped to The block -A- is an actuating arm -B- which is made from a material with a semi-rigid characteristic such as a thin spring steel or plastic. A weight -D- is fixed to the bottom of the the arm -B- and this weight is allowed free movement so that gravity acting on the weight causes the actuating arm -B- to bend. The amount of bending will depend on the choice of material for the arm -B- and the weight of -D- No bending will occur with the actuating arm in the vertical plane.

Fixed to the actuating arm -B- is an electronic sensor -C- which, when connected as an input to appropriate circuitry, will generate a signal which represents either linearly or non-linerarly, any bending moment experienced. The sensor is shown on one side of the actuating arm but it could be on either side, or 2 sensors could be fixed to the actuating arm in a configuration where the two sensors work independently or in tandem.

Datum condition is established when Block -A-, the actuating arm -B- and the weight -D- are vertical with respect to gravity as shown in FIG1 and FIG2. If the surface to be monitored is subject to a tilt angle then the weight -D- will impart a bending moment due to gravity on the Actuating arm -B- as shown in FIG3 and FIG4. Sensor -C- will generate an output signal due to bending the sense of which will reflect whether the surface to be monitored changed in a clockwise direction as illustrated by FIG3 or an anticlockwise direction as shown in FIG4.

Such a sensor is any type which responds to mechanical deflection or strain such as Piezo-Electric, resistive strain guage or semi-conductor material or light deflection by use of a light source and reflector or light receiver. Infra red, capacitive, and ultra sonic means could be adopted to measure the amount of deflection. The sensor is connected to the control circuity via wires -E- and -F-.

Fig 5 shows the signal resulting from deflection of the assembly through a complete rotation.

The signal generated, Vo ≐ G x K x Sin(theta)

Where G = Gravity K = Mechanical constant Sin(Theta) = gradient angle.

The natural resonant frequency of the combination of the Actuating arm -B-, the sensor -C- and weight -D- depends on their respective mechanical parameters but by the correct choice of material and weight it is possible to achieve resonant frequencies significantly higher than the typical pendulum frequencies mentioned earlier e.g. 30hz.

In practise, using piezo-electric sensor elements it has been possible to detect angular changes down to 0.1deg or less.

The surface to be monitored to which block -A- is fixed could be either the lift chassis which follows the rail angle, or the seat frame which is required to remain in a controlled position so that the seat is level.

In practise it is desirable to fix the sensor to the seat frame so that the sensor can detect small changes of angle either side of the vertical datum position mentioned earlier. Thus the control loop maintains the sensor assembly as near as possible to the vertical plane thoughout the travel of the stairlift. The system is an error based control loop and the electronics and follow-up mechanism is designed to keep the error within an acceptable limit which is in practise less than plus or minus 2 degrees.

Any designer should ensure that suitable safety circuits are incorporated so that should the seat become displaced by more than a present amount of say, + or - 5Deg then some sort of Brake is engaged.

A Block diagram of the electronic control loop is shown in Fig 6 Point -H- is the zero degree demand reference which is summed with the postion feedback signal from block -M-. This is fed as input to Error Amplifier -J-. The electric motor is shown by block -K- and the formula represents the transfer function. The motor drives through gearbox -L- with a reduction ratio shown as 1/N times. The signal at -N- represents the seat position and this sets the angle of the Position sensor -M- which is the circuit associated with the sensor which is the subject of the patent application.

The formulae are explained as follows.
A1 = Error Amplifier gain.
K1 = Accelleration constant
K2 = Speed Constant
N = Reduction gear ratio
K3 = Position Sensor Constant
K4 = Position sensor resonant frequency constant
S = Differentiation ie d/dt

In the case of the Electronic seat levelling unit it is desirable, though not necessarily essential, to have input information from a combination of the sensor described and a seperate pendulum device. The pendulum will give an absolute value of gradient in the event of the lift being switched off on a gradient, and compensates for long term drift.

A more elaborate arrangement could be used to stabilise a platform on a ship. In this case sensors would be fitted in the Pitch axis and the Roll axis.

When using the sensor described above in a stairlift then the signal from the transducer is subject to a combination of forces including a rotational accelleration component. This is caused by the rotation of the seat during changes of gradient.
This rotational accelleration produces a negative output component which is subtracted from the true positional component in terms of vector magnitudes and angles.

This negative component rapidly becomes large when compared to the position component as the accelleration increases as shown :-

Position component = 9.81 x K x sin wt V

where wt = angular change rate x time
K = accelleration constant in volts per degree
9.81 = gravity constant

Accelleration Component = - K w(Sqrd) R sin wt derived from d(Sqrd) wt/dt(Sqrd)

Where R = displacement distance between the centre of the sensor mass and the central point of rotation (The rotation axis)
Note the negative sign.

The output becomes :-

9.81 K sin wt - L w(Sqrd) R sin wt = Ksin wt (9.81-w(sqrd)R Volts

The closed loop control of seat positioning becomes unstable when w(sqrd)R is equal to or greater than 9.81

A further adaption to the sensor described above is the ANNULAR RING INCLINOMETER this is a refinement to the basic sensor described earlier. The effect of the refinement is to reduce the value of R, and therefore the component due to accelleration, to a minimum.

This is done by the unique way that the sensor mass is evenly distributed about the axis of rotation as shown in Figs 7 & 8

In the previous example the weight -D- in Fig 1 and 2 has been replaced with a ring -O- which is free to move and cause deflection to the arm -B- consequently to the sensor -C- as a result of the block -A- to which the assembly is fixed tilting.

The axis of rotation -P- is in fact the centre of the bearing about which the seat frame rotates.

This arrangement reduces the value of R to a minimum which significantly improves the performance of the closed loop when responding to angular deflection in the presence of a rotational component.

CLAIM

1.
An Electronic Sensor attatched to a flexible arm which is clamped at one end to a point which, through its normal operation, is subject to changes in angle with respect to the horizontal plane. At the other end of the arm is a weight. This weight is arranged to be evenly distributed around the axis of rotation so as to minimise the effect of the rotational accelleration component.

2.
The assembly referred to in 1 used where the accelleration or decelleration of the assembly results in a signal due to the inertia of the weight causing deflection of the flexible arm.

Amendments to the claims have been filed as follows

CLAIMS:

1. A stair lift comprising a seat arrangement and a chassis arrangement arranged to rotate relative to one another, the seat arrangement being provided with an inclinometer comprising an inertial mass attached to a stiff arm provided with a strain gauge, wherein the centre of mass of the inertial mass is substantially located at the axis of rotation of the stair lift seat arrangement relative to the chassis arrangement.

2. A stair lift provided with an inclinometer comprising an inertial mass attached to a stiff arm, and further provided with a pendulum, both of which are arranged to monitor inclination.

3. A stair lift according to claim 2, wherein the inclinometer output is used to control seat inclination over short periods, and the pendulum is used to correct any accumulated error in the seat inclination over longer periods.

4. A stair lift according to any preceding claim wherein the inertial mass is substantially circular in shape.

5. A stair lift according to any preceding claim wherein the inertial mass is substantially annular.

The Patent Office

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Application No: GB 9703570.3
Claims searched: 1-2

Examiner: Andrew Bartlett
Date of search: 25 February 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G1N (NAGD8, NACNI); B8L (LB, LCA, LFB)

Int Cl (Ed.6): B66B 9/08; G01B 5/30, 7/16 & 7/24; G01C 9/00. 9/02, 9/08, 9/14 & 9/16

Other: ONLINE:- WPI, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2301811 A	(BISON BEDE LTD) See page 9 in particular	1 at least
A	EP 0172301 A1	(ELTA ELETTRONICA) See fig 3 for example	1 at least
A	WO 95/29867 A1	(JOHANSSON) See page 6 lines 18-34 in particular	1 at least

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